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Great Lakes Update

Impacts of El-Nino Conditions on the Great Lakes

During the winter of 1997-98, people from New Zealand to South America and north to the Arctic Circle have witnessed one of the strongest *El-Nino* events on record. This phenomenon, predicted to conclude in April when Pacific waters return to more normal temperature patterns, has been tied to a severe drought in Australia, flooding and mud slides in California, powerful western-hemisphere storms and a very mild Great Lakes winter season. In simple terms, *El-Nino* is the pooling of warmer Pacific surface waters along the Peruvian coast which can change the weather patterns globally, including the jet stream patterns.

Normal Jet Stream Pattern

The jet streams are fast-moving (around 80 mph) high-altitude (around 40,000 feet) rivers of air that travel from west to east around the globe. More importantly, they act as boundaries between warm air to the south of the stream and cold to the north. During an average winter the jet stream sags out of central Canada then through the northern plains, Ohio Valley and off the central east coast (see figure).

During an *El-Nino* year, the milder ocean water temperatures disrupt the jet stream patterns and the northern jet stream is forced northward well into Canada, trapping the frigid Arctic air near the north pole. The dominating jet stream flow generally becomes more west to east, drawing milder Pacific air across the Great Lakes. This doesn't mean that the Great Lakes will be void of cold air - just that the outbreaks will be less frequent and shorter lived.

In 1998, many Great Lakes cities have recorded average February temperatures in the top five warmest ever recorded at those locations. What was unexpected was the amount of heavy precipitation that fell from some very powerful storm systems.

During the 1997-98 *El-Nino* event, the air flow pattern has come from a marine source region (the Pacific) and the air masses have been very moisture-laden compared to those originating from the Polar region. The direct result has been cloudy, drizzly weather with little range between daily high and low temperatures. Warm, moist air also carries more storm producing energy, which creates higher winds, stronger storms and heavier precipitation when it clashes with Arctic air. If *El-Nino* forecasters were incorrect about anything, it would have been an underestimation of the power of the storms that occurred. The strength of storms passing through the Midwest so far in 1998 has been more characteristic of springtime activity than the more passive but frigid "Alberta Clipper" systems typical during a winter.

Scientists are using tree rings from the southwest U.S. and Mexico that date back to the 1700's to reconstruct the *El-Nino* patterns and dates. Heavier *El-Nino* rainfall out west produces thicker growth rings; drought conditions result in very narrow ring patterns. This method was used to discover evidence of an increase in *El-Nino* activity since 1880, when a massive *El-Nino* event effected the west. *El-Ninos* have occurred on the average of every 5-7 years.

La-Nina is the opposite swing in eastern Pacific ocean temperatures where colder than normal waters pool off the west coast of Peru. Corresponding shifts in weather patterns occur in North America where the southern U.S. swelters under above average temperatures and little rain while the north sees cooler and rainier conditions. *La Nina* has tended to recur approximately every 4 years in the 20th century instead of once a decade as in the 1800's. The Great Lakes region may experience a *La Nina* in the fall of 1998.

Because of the jet stream anomalies caused by *El-Nino*, normally warm and cold regions encountered dramatic shifts. On one day this winter, snow fell in Guadalajara, Mexico, while it was in the 50's in Saskatchewan, Canada. The severe ice storm and heavy rain that fell over the Lake Ontario basin during January 5-9 would have likely been just a heavy snowfall for the region under normal winter weather patterns. Instead, upwards of 4 million people lost power for more than a week in what *Time Magazine* cites as "one of Canada's greatest natural disasters ever," and Lake Ontario's level rose eleven inches in just a matter of days.

Winds accompanying these *El-Nino*-enhanced storm systems have prompted several gale warnings across the Great Lakes. Shoreline erosion from driving 6-10 foot waves has resulted in the recent destruction of several homes on Lake Michigan. The city of New Buffalo, Michigan has been threatened with the loss of its municipal drinking water as the pumping station's shore protection was washed away by northwest gales on March 9, 1998.

The milder *El-Nino* conditions have prevented the formation of shore ice, which protects shorelines from just such pounding wave damage. With average daily

Storms are a significant contributor to bluff erosion such as has occurred at this Shoreham, Michigan location.

air temperatures being an amazing 5-10°F above normal, ice formation across the Great Lakes was almost non-existent throughout this winter. Lake Superior remained ice-free for the majority of the winter (except for thin ice in Keewenaw Bay, around the Apostle Islands and northwest of Isle Royale). According to **Ray Assell** of the Great Lakes Environmental Research Laboratory, it is a rarity to not see at least some ice formation in the shallow western end of Lake Erie every winter. During the cold late fall and early winter across the region, data show that the Great Lakes had completed their seasonal water temperature stratification, which must occur before substantial ice formation begins. By the time the lakes were ready, the weather shifted to a milder pattern and the ice-formation step never really materialized. Also contributing was the sparse number of days where the average daily temperature across the southern Great Lakes dipped below freezing. Detroit, Michigan has yet to record a single digit temperature this winter...for the first time since records have been kept.

Great Lakes bulk carriers took advantage of the mild and tranquil weather through last October, shipping more tonnage than any year since 1982 and completing all delivery contracts early or on time. This meant that crews could stay home instead of pushing to complete deliveries in late December. **Rick Harkins** of the Cleveland, Ohio-based Lake Carriers Association said most companies took the winter off because of the seasonal closing of the Soo Locks, but plan to start the 1998 season early since ice is not a factor. The St. Lawrence Seaway also took advantage of the warmth by opening to bulk carriers almost 1 week earlier than scheduled.

Those relying on winter weather to ply their trade on the Great Lakes had to find alternative sources of income this winter as the primary industry - ice fishing related supplies and services - has had to take the winter off. Ice fisherman look for at least 6 inches of solid thickness before venturing out, something that hasn't come close to happening.

Petty Officer First Class **Philip Myers** of the U.S. Coast Guard's Group Detroit says "we have been fairly busy pulling people off of the ice that does exist. And at that, (the ice) has been marginally stable, and only in Saginaw Bay." PO Myers said Group Detroit follows the National Weather Service's *freezing degree days* (FDD) to assist in gaging lake ice formation. The area normally averages around 700 FDD per winter; so far this year it stands at 167. "Only eight hours or so have been logged to 'ship assistance' (ice breaking, towing, etc.) this year, as opposed to several hundred a month. There is so little ice, we had to cancel our ice rescue competition on Saginaw Bay this year." So instead, Coast Guard personnel have been painting and cleaning ships for the boating season.

Altered jet stream patterns also mean different storm tracks from a normal winter, which often results in seemingly continuous precipitation in some areas and almost arid conditions only a couple of hundred miles away. Such has been the case with Lake Superior in 1997-98. A victim of below normal precipitation every month since January 1997, the lake has seen its level drop in excess of 1 foot in one year.

Of added concern is the magnitude of snowpack across the Lake Superior basin that has been almost insignificant compared to the near record amounts of 1997. The lack of continuous cold air has contributed to a freeze/thaw cycle that has spread snowmelt runoff across much of the winter and kept the snowpack on the northern Great Lakes watersheds substantially lower than normal. This in turn has produced an earlier snowmelt runoff and reduced the stream flood threat. Only minor in-bank rises are expected for most northern inland rivers. With Lake Superior resting close to its long term average level and substantially less inflow anticipated, the lake level may lag behind its normal seasonal increase in 1998.

Another facet to this story is the evaporation of water from the surface of the Great Lakes. Evaporation of lake surface water is a very important element in the annual rise and fall of water levels. While the Great Lakes remained ice-free through the bulk of the winter, increased evaporation has not occurred. The 1997-98 air flow across the lakes was very moist (already carrying water) and close to the temperature of the lake surfaces. In physics, molecules move from warm to cold; the greater the contrast, the greater and faster the movement. When air and lake temperatures are similar in temperature, relatively little uptake (evaporation) occurs. But when bone-chilling cold and dry Arctic air masses cross the open waters of the Great Lakes, the resulting evaporation is greatest. This is evidenced by lake-effect snows on the leeward side of the lakes common during most winters.

For next year, hydrologic conditions look to be more typical, as the National Weather Service outlooks indicate a return to more seasonal conditions, if not slightly cooler than normal, for the Great Lakes.

Bluff Erosion During El-Nino Conditions

Evidence suggests that the same meteorological conditions that cause increased precipitation and a rise in lake levels, whether during El-Nino conditions or not, may also be responsible for a rise in both the number and severity of storms during the same period. It would also be true that increased precipitation would increase groundwater flow.

Waves are the primary erosion force along Great Lakes coasts. Wave forces are greatest, of course, during storms. Along much of the coastline, most of the erosion occurs as a result of storms and many of the most dramatic episodes of bluff erosion occur during storms. At such times, bluff recession can accelerate rapidly, the end result of which is illustrated in the photograph of the residence in Shoreham, Michigan, shown previously.

In addition to the increased wave energy associated with the strong winds that produce waves, the duration of the storm, and the temporary increase in lake levels, (storm surge that usually accompanies a storm) all affect the potential for damages. As an example, high waves were present during the severe storm that occurred on Lake Michigan on March 9 of this year. However, much of the damage appears to have been the result of the accompanying storm surge, as high as 3 to 4 feet in some locations, that allowed the storm waves to overtop shore protection structures.

Periods of increased lake levels as a result of weather patterns, can range from as short as several hours as a storm front passes, to several months or years as a result of higher precipitation, or shifts in climate regimes. At some locations, most notably on Lake Erie, the oscillation of a storm surge may create a seiche.

One of the most important contributors to the erosion process, particularly on bluff shoretypes, is ground-water. Groundwater seeping out of the bluff can be observed at many locations along the coastline. Groundwater can erode the bluff directly as flowing water, by acting as a lubricant between the various till, clay, and sand layers, or by adding additional weight to the bluff. There were several instances of dramatic bluff failures over the past year, most notably in Allegan County, Michigan. These bluff failures occurred during periods of heavy rain, but relatively calm wave conditions. Bluff failure as a result of groundwater can occur with, or without the presence of waves, but in some respects it is like the "chicken or the egg" since the removal of the eroded material at the base of the bluff by the waves sets the stage for the next round of bluff failure.

Due to irregularities in bluff composition, human activities, and because natural processes including storms do not occur at regular intervals, bluff recession tends to be episodic; that is higher one year than another. When averaged over a period of several decades the short term recession rates will become less apparent. These long term averages can be extremely useful in evaluating the general erodability of the coastline. But very often this is not as important as being able to predict recession over a shorter time interval (days, weeks or months). An understanding of the short term versus long term erosion characteristics becomes all the more important if the bluff at a particular location is subject to long periods of little, or no, recession separated by short periods of high recession.

As an example, consider two lakefront properties, one on a sand bluff, the second on a more clay-like or “till” bluff. In this example let’s assume that the long term, average bluff recession rate for both bluff types is 1 foot per year. On the average then, a structure located 30 feet from the bluff crest should be safe for about 30 years. For many purposes the long term, average recession rate is adequate. But for the owners of the two properties in our example that may not be enough.

Very generally speaking, dune bluffs tend to recede at a fairly constant rate. At an average of about 1 foot per year in our case. For a dune bluff type then, the long term, average bluff recession rate would also be a good indicator of the recession that could be expected every year. The dune bluff property owner could expect that for every year that passed, the bluff crest would be about 1 foot further inland.

Till bluffs, generally, tend to erode episodically. It is not uncommon at all for till bluffs to be somewhat stable for long periods and then to recede a great distance in a short time. For our example, the till bluff may remain stable for 29 years and then recede 30 feet the following year. On the other hand, the till bluff might remain stable for 2 years, recede 30 feet the following year, and then remain stable for 27 more years; or be stable for 10 years, recede 20 feet, be stable for another 18 years, then recede 10 feet. Site specific conditions would govern how the recession progressed.

The long term, average bluff recession rate over the 30 year period would still be 1 foot per year, but how that recession occurs is very different. The owner of the sand bluff property may not be concerned with short term recession since it is more or less constant from year to year, but the till bluff property owner would be very concerned, not knowing when exactly the next bluff erosion event might occur, or how much recession might occur when it does.

Making short term recession predictions can be difficult, and would generally require a detailed site-specific study. However, some general assessments can be made. The following conditions, might suggest an increased risk of approaching bluff failure: an inherently episodic erosion prone bluff type; over-steepened bluff slope; the presence or increase in groundwater flow; high lake levels; storms (or an increase in the number and strength of storms); and interruptions in sand supply.

Frequently Asked Questions Revisited

How are the Great Lakes controlled?

Whenever Great Lakes water levels are discussed, questions about the control of Lakes Superior and Ontario outflows arise. Lake levels and outflows from all of the Great Lakes are subject to natural climatic, hydrologic and hydraulic factors. However, outflows from Lakes Superior and Ontario are controlled by artificial means. The outflows from Lakes Michigan-Huron (hydraulically connected through the wide and deep Straits of Mackinac), Lake St. Clair, and Lake Erie are controlled by nature.

Regulation of Lakes Superior and Ontario has provided controls for the outflows of these two lakes since 1921 and 1958, respectively. The goal of the regulation plans for these lakes is to keep their levels within a specified range, near their long-term averages. The outflow controls are provided by a series of hydropower facilities, navigation locks, and gated control dams. The control of the outflows of these lakes allows the levels to be maintained within a smaller range than is possible without regulation. Lake Superior outflows are currently regulated using Plan 1977-A, while those of Lake Ontario are regulated using Plan 1958-D.

What is Plan 1977-A and how is it implemented?

In October 1979, Plan 1977 was activated, incorporating a philosophy of systemic regulation. Plan 1977 was revised in 1990 to bring the regulation plan up-to-date and improve operational efficiencies. The revised plan known as Plan 1977-A is the current operating plan. Use of Plan 1977-A was approved in 1990 by the International Joint Commission (IJC) and is implemented by the IJC's International Lake Superior Board of Control. It is the latest in a series of regulation plans which incorporate a balancing technique between the levels of Lakes Superior and Michigan-Huron.

How have recent Lake Superior outflows compared with their averages and what can be expected in the near future?

The chart below shows that the monthly outflows from Lake Superior have been below average since

September 1997 (except for March 1998), and are forecasted to remain near or below average for at least the next six months. This forecast is based on lake level conditions at the beginning of April and assumes average water supplies to the lake. As the year progresses and actual conditions are factored into Plan 1977-A, outflows are likely to be different from this current forecast. The chart shows that the monthly outflows have been significantly below the outflows for the same months of the previous year, and are expected to remain so at least through August. This shows that Plan 1977-A is working to bring the Lake Superior outflows down in response to the relationship of Lake Superior levels to Lakes Michigan-Huron levels.

Why have Lake Ontario levels risen so dramatically over the last three months?

The level of Lake Ontario has risen dramatically from a December 1997 mean level of about 244.72 feet to a March mean level of 246.52 feet, a rise of about 22 inches. For the same period in 1996-97, the rise in Lake Ontario water levels was about 11 inches. The long-term average rise from December to March is about 5 inches.

The 22 inch rise resulted primarily from the excess precipitation over the basin during the last three months. A total of 10.54 inches of rain fell during the January through March period. The long-term average for this period is 7.69 inches. The excessive precipitation combined with an early snowmelt, caused by warmer than normal temperatures, has resulted in almost double the usual water supply to the basin, an average of 94 thousand cubic feet per second per month (tcfs-m) as compared to the long-term average of 48 tcfs-m for the January through March period.

What are the Lake Ontario outflows expected to be in the near future?

As of the date of this publication, Lake Ontario outflows were at 360,000 cubic feet per second, an extremely high discharge rate. Outflows expected through the remainder of April will likely remain high. Outflows from Lake Ontario are adjusted on a weekly basis, and significant changes can occur from month to month.

Notes:

Additional information to supplement the above article can be obtained from Detroit Districts Internet Home Page at: ***http://sparky.nce.usace.army.mil***. Information on erosion, bluff recession, or other coastal processes can be obtained by accessing the ***"Coastal Engineering"*** option on the Home Page menu.